REMARKS

This preliminary amendment is being filed contemporaneously with this RCE Application.

It is submitted that no new matter is being entered by this preliminary amendment. Applicant's representative wishes to thank the Examiner for the courtesy extended in the telephone conference of April 25, 2004.

Claims 1-19 are pending in the current application, claim 19 having been withdrawn from consideration by the Examiner. Claims 1-18 are rejected. The applicant has amended claims 1 and 2 to place the designation of the surface finish in proper form as discussed below. The applicant also withdraws claim 19 from consideration by this amendment.

Claim 7 has been amended as suggested by the Examiner.

In the Office Action dated November 13, 2003, the Examiner indicated that the 1.131 Affidavit submitted by the Applicant was deficient in that the Affidavit did not include a copy of the invention disclosure reference in the affidavit. Applicant herein provides a copy of the invention disclosure form prepared by the inventor. Dates have been removed from the form as permitted by current practice. This document clearly shows the preoxidation aspect of the instant claims. The surface roughness aspect is discussed at **D. Description and Operation** at numeral 3) which discusses the texturing aspect of the invention. The texturing was performed and completed as indicated in the invention disclosure, although the actual measurements of the textured surface finish are not noted in the disclosure. Applicant submits that all of the Examiner's objections to the affidavit are satisfied by the submittal of this invention disclosure. Handwritten notes on this disclosure that are not signatures were made by the undersigned attorney during discussions with the inventor while preparing the application and are not part of the disclosure.

Claims 2-18 are rejected under 35 U.S.C. §112 second paragraph. The Examiner has taken the position that it is impossible to ascertain the metes and bounds of the numerical range of the surface finish. The applicant has stated that applicant has used the English convention

(microinches) inasmuch as the English measuring system is the standard for measurement in the United States. The Examiner continues to assert that it cannot be determined whether one skilled in the art would recognize applicant's specification as indicating the English System of microinches. Applicant hereby submits a section from Marks' Standard Handbook For Mechanical Engineers, Tenth Edition (1996) as evidence of what one skilled in the art would understand by applicant's designation of surface finish in this application. First, applicant notes at page 13-70, left column under the heading **MEASUREMENT**, that "the United States and 25 other countries have adopted the roughness average R_a as the standard measure of roughness." As indicated on page 13-69, roughness can be given in microinches or in micrometers and reference is specifically made to Table 13.5.3. Listed side by side are the Series surface roughness average values R_a in micrometers and microinches. The roughest surface is listed at the bottom right of the table and the smoothest surface is listed at the top left of the table. The preferred designations are listed in bold print. The preferred designations for roughness in microinches are 1000, 500, 250, 125, 63, 32, 16, 8, 4 and 2. The corresponding values in micrometers are 25.0, 12.5, 6.3, 3.20, 1.60, 0.80, 0.40, 0.20, 0.10, and 0.050. Applicant notes that each of the preferred designations in micrometers is followed by a decimal point and a digit. Applicant has referred in the claims to surface roughnesses of 16, 32, 63, 125. It should be clear to one skilled in the art that these designations refer to the preferred designation in microinches, as each of the values in applicant's claims is listed in Table 13.5.3 as one of the preferred designations in the microinch column, and the values include no decimal points and subsequent digits. There are not any corresponding designations for these values in the listing of micrometers in Table 13.5.3, either in the preferred designations (boldface) or in the remaining designations (regular print). It seems inconceivable to the applicant that one skilled in the art could interpret the values listed in her specification as anything but in microinches. To reach any other conclusion, one skilled in the art would have to intentionally ignore the well-accepted information set forth in Table 13.5.3.

It is not disputed that the applicant has indicated in her specification the roughness average R_a which has been adopted by the United States. The question raised by the Examiner then can be reduced to whether the roughness average specified in the specification is in microinches or micrometers, as those are the choices available for R_a as noted in the attached

article. To conclude that he roughness average is specified by the applicant in micrometers, (1) the applicant was so lacking in skill that she specified roughness values not only that are not preferred designations, but are not among the commonly listed designation for micrometers; (2) that the applicant, who is so knowledgeable as to create new micrometer designations intermediate the ones commonly used and set forth in Table 13.5.3, failed to include the decimal point and subsequent digit for each of the values as required by the R_a listings when provided in micrometers, and (3) utilized surface roughnesses beyond those commonly accepted (32 R_a, 63 R_a and 125 R_a, if interpreted to refer to microinches are each above the maximum surface roughness of 25.0 listed in Table 13.5.3) Alternatively, one skilled in the art could conclude that applicant did not include the word "microinches" when referring to surface finish roughnesses of 16 R_a, ,32 R_a, 63 R_a and 125 R_a. Applicant respectfully submits that any person reasonably skilled in the art would arrive at the latter conclusion, and would clearly understand that applicant was referring to a surface finish in microinches. Based on the submittal from Marks' Standard Handbook For Mechanical Engineers as representative of the minimum knowledge of one skilled in the art, applicant requests withdrawal of the rejection of claims 2-18 under 35 U.S.C. §112. Applicant further wishes to clarify the Examiner's statement. Applicant has noted that surface finish is significant as stated at page 7 of the 25 September 2003 amendment, but did not state it is critical.

Claim 1-4, 6-11, and 14-17 are rejected under 35 U.S.C. §103(a) as unpatentable over the combination of Warnes et al. (U.S. Patent No. 6,472,018) in view of EP 969117; claim 5 as unpatentable over the combination of Warnes et al. in view of EP 969117 and further in view of Vakil (U.S. Patent No. 6,495,271), and claim 5 as unpatentable based on the combination of Warnes et al. in view of EP 969117 and further in view of Murphy (U.S. Patent No. 5,716,720). Applicant believes that the affidavit as supplemented by the attachments, requested by the Examiner effectively remove Warnes et al. as a reference. Since Warnes et al., the primary reference relied upon by the Examiner has effectively been removed as a reference, no further response is required as the combinations set forth are infirm without Warnes et al.

Claims 1-4 and 6-18 are rejected under 35 U.S.C. §103(a) as unpatentable over EP 969117 in view of Pasta et al. (U.S. Patent No. 5,658,614 and Murphy. The Examiner states:

EP 969117 discloses the following limitations of claims 1 and 2:

- "providing a gas turbine......high temperatures" (0013 and 0015);
- "applying a thin layer......the component" (0019);
- "exposing the thin layer of platinum to a source of aluminum for a preselected time" (0019);
- "grit blasting" the PtAl coating "using a grit of preselected ......Ra; then'" (0019);
- "providing" the PtAl coating "with a clean......gradients of nickel, aluminum and platinum" (0019 in that the grit blasting of the PtAl is the same as that claimed and disclosed by applicants to achieve a 'clean, uniform surface free of oxides and local gradients...." and hence would inherently provide the PtAl with these features); and
- "preoxidizing the" PtAl coating by heating it in a high temperature treatment specifically performed for this purpose to form a thin layer of pure alumina) (0016, oxidizing the clean PtAl that was grit blasted would provide pure alumina).

EP 969117 does not disclose that a single phase PtAl layer is formed or that the heat treatment of the aluminide to form alumina is performed by "heating the component in a preselected partial pressure of oxygen......at a preselected rate." However, because Basta discloses at col. 2, lines 1-20 that single phase PtAl bond coats have advantages over two phase PtAl bond coats of not having metastable phase assemblages and thicknesses, being sensitive to thermal fatigue cracking, or rumpling and Murphy discloses that heat treating single phase PtAl bond coats under the claimed conditions is effective for providing the stable alumina scale desired in EP 969117 (Col. 5, lines 55-25 and col. 6, lines 15-25), it would have been obvious to have provided a single phase PtAl in the manner prescribed by Basta to achieve the disclosed advantages thereof and to heat treat to form the alumina under the conditions of Murphy because doing so would have expected to be effective for providing said alumina layer.

The limitations of the dependent claims are disclosed as follows:

- Clams 3 and 4 (EP 969117 at 0013 and 0015);
- Claims 6 and 7 (Basta at col. 5, line 50 to col. 6, line 15);
- Claims 8-11 (EP 969117 at 0019);
- Claims 12-17 (Murphy at sections cited above, please note that minimizing time to reach the heat treatment temperature would have been obvious for the reasons set for above); and
- Claim 18 (EP 969117 at 0019).

Applicant respectfully traverses this rejection. The Examiner has gratuitously added in that preoxidizing the PtAl coating in EP 969,117 provides pure alumina. The pure alumina taught by Applicant is the direct result of controlling temperature and partial pressure of oxygen. Clearly, when EP 969,117 is considered as a whole, there is a complete lack of appreciation of

formation of "pure alumina." MPEP §2141.02 requires that the differences between the prior art references and the invention as a whole be considered. MPEP §2141.02 provides as follows:

SECTION---2141.02 Differences Between Prior Art and Claimed Invention

Ascertaining the differences between the prior art and the claims at issue requires interpreting the claim language, and considering both the invention and the prior art references as a whole. See MPEP Section 2111 - Section 2116.01 for case law pertaining to claim interpretation.

THE CLAIMED INVENTION AS A WHOLE MUST BE CONSIDERED

In determining the differences between the prior art and the claims, the question under 35 U.S.C. 103 is not whether the differences themselves would have been obvious, but whether the claimed invention as a whole would have been obvious. Stratoflex, Inc. v. Aeroquip Corp., 713 F.2d 1530, 218 USPQ 871 (Fed. Cir. 1983); Schenck v. Nortron Corp., 713 F.2d 782, 218 USPQ 698 (Fed. Cir. 1983) (Claims were directed to a vibratory testing machine (a hard-bearing wheel balancer) comprising a holding structure, a base structure, and a supporting means which form "a single integral and gaplessly continuous piece." Nortron argued the invention is just making integral what had been made in four bolted pieces, improperly limiting the focus to a structural difference from the prior art and failing to consider the invention as a whole. The prior art perceived a need for mechanisms to dampen resonance, whereas the inventor eliminated the need for dampening via the one-piece gapless support structure. "Because that insight was contrary to the understandings and expectations of the art, the structure effectuating it would not have been obvious to those skilled in the art." 713 F.2d at 785, 218 USPQ at 700 (citations omitted).).

See also In re Hirao, 535 F.2d 67, 190 USPQ 15 (CCPA 1976) (Claims were directed to a three step process for preparing sweetened foods and drinks. The first two steps were directed to a process of producing high purity maltose (the sweetener), and the third was directed to adding the maltose to foods and drinks. The parties agreed that the first two steps were unobvious but formed a known product and the third step was obvious. The Solicitor argued the preamble was directed to a process for preparing foods and drinks sweetened mildly and thus the specific method of making the high purity maltose (the first two steps in the claimed process) should not be given weight, analogizing with product-by-process claims. The court held "due to the admitted unobviousness of the first two steps of the claimed combination of steps, the subject matter as a whole would not have been obvious to one of ordinary skill in the art at the time the invention was made." 535 F.2d at 69, 190 USPQ at 17 (emphasis in original). The preamble only recited the purpose of the process and did not limit the body of the claim.

> Therefore, the claimed process was a three step process, not the product formed by two steps of the process or the third step of using that product.).

Applicant therefore refuses to accept the premise thrown out by the Examiner that EP 969,117 forms pure alumina. When considered as a whole, it is clear that this reference does not distinguish that different grades of alumina may exist, a fundamental teaching of the present invention. Rather, when EP 969,117 is considered as a whole, it is clear that it only requires that alumina be formed, and is not particularly detailed about how the alumina is formed. If the Examiner is to persist in this rejection, he is requested to specifically identify those portions of EP 969,117 that teach the formation of pure alumina and how the pure alumina is achieved.

The Examiner further relies on Murphy for the teaching that heat treating single phase PtAl bond coats under the claimed conditions is effective for providing the stable alumina scale desired in EP 969117. Once again, when the reference is considered as a whole it is seen that it does not disclose applicant's invention. While the Examiner cites the formation of a thin, tightly adherent alpha alumina layer on a *diffusion aluminide* layer (emphasis added) that Murphy has designated as MDC-150L, the Examiner has failed to recognize exactly what the MDC-150L layer is. Applicant submits that it is not the single phase PtAl layer taught by applicant. Rather, the diffusion aluminide layer taught by Murphy is a duplex structure formed by a complicated process set out at columns 3 and 4 of the Murphy patent. This MDC-150L bond coat has an inner diffusion zone and an outer layer region comprising a platinum modified intermediate phase of aluminum and nickel (or cobalt depending on the superalloy composition), see col. 3, lines 56. This intermediate phase forming the outer layer is the single phase discussed in Murphy and is a metallic solid solution including nickel (or cobalt), aluminum and platinum and the single phase to which the platinum is diffused is shown on the phase diagram of Figure 2 of Murphy. The MDC-150L bond coat is formed by the process set forth in col. 4, lines 45+ - col. 5, line 5. This clearly is not the bond coat that is oxidized by applicant to form pure alumina as applicant teaches, nor is applicant's bond coat formed by the method set forth in Murphy. When the prior art is considered as a whole, it is clear that applicant's method is not taught by the suggested combination.

It is not proper merely to catalog the various elements disclosed in the prior art in order to achieve applicant's invention. There must be motivation to combine the references, and when

the references are considered as a whole, they must yield applicant's invention when considered as a whole. Here, even if the combination is proper, which applicant is not willing to concede, when the prior art is considered as a whole, the combination does not yield applicant's invention. As noted, there is nothing to suggest in EP-969,117 to form a pure alumina scale on a single phase platinum alumina. Thus, there is no motivation to combine EP-969,117 with Basta and Murphy to form a pure alumina scale. While Murphy teaches the formation of an alumina scale on a single phase diffusion bond coat, it is not a PtAl bond coat, but rather on a bond coat designated as MDC-150L which clearly is not simply a PtAl bond coat. Thus, even if the combination was proper, when MDC-150L bond coat of Murphy, which must be substituted for the bond coat set forth in EP-969,117 if the oxidation set forth in Murphy is to be accomplished as suggested by the Examiner, is applied to EP-969,117 and oxidized in accordance with the parameters of Murphy, one does not achieve the claims as set forth by applicant.

Applicant respectfully requests withdrawal of the rejection of claims 1-4 and 6-18 based on the combination of EP-969117, Basta et al. and Murphy and requests allowance of these claims.

Claim 5 is rejected under 35 U.S.C.§103(a) as unpatentable over EP 969117 in view of Basta et al. and Murphy as applied above and further in view of Vakil. The Examiner states:

> Basta discloses electroplating to deposit the thin Pt layer rather than CVD. However, because Vakil discloses at col. 3, lines 35-43 that both electroplating and CVD are effective methods for depositing a thin layer of Pt on a nickel based superalloy, it would have been obvious to use either electroplating or CVD to deposit the Pt layer as both methods are art-recognized equivalents for performing said step and hence one would expect to achieve equivalent results using either method.

Applicant traverses these claims. The combination of EP-969117 in view of Basta et al. and Murphy has been discussed above and is equally applicable here. Vakil's disclosure adds nothing that makes the infirm combination viable. Applicant respectfully requests withdrawal of the rejection of claim 5 based on this combination.

CONCLUSION

Applicant requests entry of the above amendment, withdrawal of all objections and rejection of claims 1-18, allowance of the claims, and issuance of the subject application as a patent.

If the Examiner believes that prosecution of this Application could be expedited by a telephone conference, the Examiner is encouraged to contact the Applicant.

The Commissioner is hereby authorized to charge any additional fees and credit any overpayments to Deposit Account No. 50-1059.

Respectfully submitted,

Carmen Santa Maria

Dated: April 30, 2004

Carmen Santa Maria

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Attorney for Applicant

Attachment:
1. Invention disclosure (dates removed)
2. Marks' Standard Handbook For Mechanical Engineers, Tenth Edition (1996)- pp.13-67 through 13-72

07783-0047

Method of improving the TBC life on single phase platinum aluminide by pre-oxidation

To:	GE Aircraft Engines Invention Disclosure	For Legal Operation Use
Dave Narciso Patent Attorney ☑ H17, Evendale ☐ 16004, Lynn	General Electric Company	Docket Number 13 DV 13486 Date Opened By J Mackay

Instructions

1. Using the outline given below, describe the invention fully and completely. Use as many or as few sheets as necessary for an adequate disclosure.

   A. **TITLE.** Please provide a short title of the invention.

   B. **PRODUCT.** Indicate the product line(s) to which the invention pertains (including engine designation(s) where appropriate).

   C. **BACKGROUND.** Describe the prior art (such as patents or publications) including limitations and/or problems existing therein which led to the invention and attach a copy of such prior art.

   D. **DESCRIPTION AND OPERATION.** Describe the basic structure and operation of the invention, with parts referenced by numbers on attached illustration(s) preferably no larger than 8 1/2 x11.

   E. **ADVANTAGES AND NEW FEATURES.** List the advantages and new features of the invention not found in the prior art.

   F. **ALTERNATIVES.** Describe and illustrate alternative forms of the invention.

   G. **EXECUTION OF DISCLOSURE.** Using the format illustrated below,

   EACH INVENTOR: Must **Sign and Date Each** page of the disclosure and **Each** sheet of any illustrations; and

   TWO WITNESSES: Must read, understand and **Sign and Date Each** page of the disclosure and **Each** sheet of any illustrations.

Inventor's Signature	Date	Witnessed, read, understood and signed by	Date
Irene Spitsberg		Jeffrey A Pfaendtner	
		Joseph D Rigney	

2. Send **Original and Eight (8) Copies** of the Invention Disclosure and any attached illustrations to the appropriate patent attorney.

3. **Print or Type**	Inventor	Inventor	Inventor
Full Name	IRENE T Spitsberg		
Social Security Number	121-82-4436		
Mail Drop	M85		
Telephone Number	243-0168		
Department	MPE&D		

4. **EACH INVENTOR MUST FURNISH THE INFORMATION REQUESTED ON THE REVERSE SIDE OF THIS FORM.**

6785 (12-89)

See Reverse Side

Patent disclosure letter
Irene Spitsberg

Title: Method for improving the TBC life on single phase Platinum Aluminide bond coat by the bond coat pre-oxidation heat treatment

A. Product: Turbine airfoils and other gas path hardware including blades, vanes, shroud and liners.

C. Background:

The concept of preoxidation of the bond coat prior to TBC deposition to form a thin alumina layer has been discussed in literature for over 10 years. Preoxidation of MCrAlY type bond coats has also been practiced. In 1983 patent (1), P&W describes a method for preoxidation of MCrAlY bond coat using a hydrogen atmosphere at 1975F for 4 hours. In another patent in 1993 (2), P&W describes a method for pre-oxidizing the MCrAlY bond coat in the TBC coating chamber using oxygen gas directed at the specimen prior to coating deposition. This lasts for approximately 10 minutes at a specimen temperature of 1600F. The beam then re-focused and the 7YSZ is deposited. Others also described preoxidation methods and benefits to TBC life (3,4).
It is well known that properties of ceramic/bond coat interface determine spallation resistance of the TBC system. Properties of alumina layer growing between the ceramic topcoat and the bond coat as well as the rate of the layer growth have the major impact on the stresses generated at the critical interface and the interface strength. So, the idea itself that the bond coat preoxidation treatment can result in "a better" properties of the grown oxide and/or reduce the oxide growth rate (by altering the oxide microstructure and phase composition) has been developed in many papers. However, it is still not clear what exactly properties or their combination of the oxide film should be achieved to benefit the TBC. From the analysis of published literature, it follows that the following factors could be important: completion of the oxide phase transformation form transient oxides to dense alpha – alumina, purity of the oxide, the kinetic of transition from internal to external oxidation, formation "defect free" contiguous layer, columnar oxide grain structure, oxide growth by inward oxygen diffusion with no lateral oxide growth.
The general approaches such as CVD deposition of the "pure" alumina film or formation of the oxide by thermal growth, with the oxide thickness being 0.25 – 25 micron, are typically described.

However, if the complexity of the process of the oxide film formation is taken in consideration along with the fact that the criteria for the "good" oxide is not well established, it becomes clear that factors such as the coating chemical composition, coating microstructure, surface conditions, etc. can be critical in a sense that the conditions of preoxidation will be very specific to the coating system. The following example shows that at conditions when the TBC life improvement as a result of

Inventor
Irene Spitsberg

WITNESSED:
Jeffrey A. Pfaendtner
Joseph D. Rigney

preoxidation treatment achieved for one type coating, no benefit is gained for the other type (Figure 1). This confirms that the optimal parameters of the preoxidation treatment are specific to the coating type.

Figure 1. Effect of preoxidation on 2 different coatings

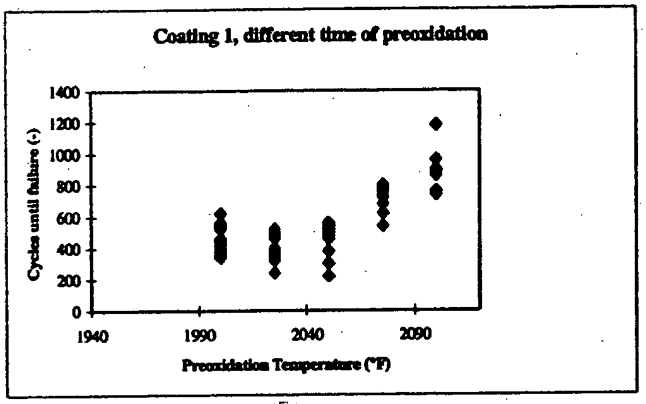

FIG 3

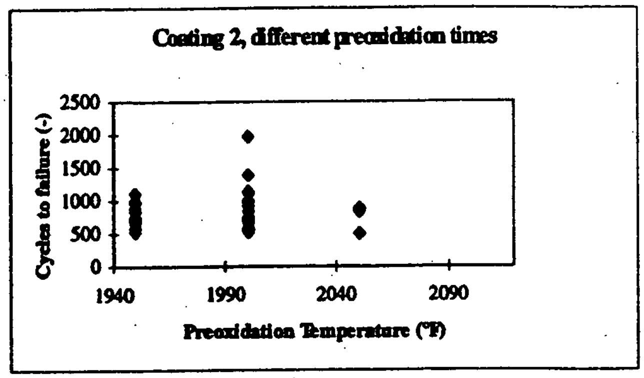

FIG 2

It is seen that whereas Coating 1 starts show a significant life improvement only at temperature close to 2100F, the temperature range of 2000 – 2050F is more beneficial for Coating 2, with the bigger overall effect achieved.

The present invention describes a set of parameters of preoxidation heat treatment for single phase PtAl bond coat at low partial pressure of oxygen.
The following examples illustrate the details of this invention.

Example 1 shows effect of oxygen partial pressure.

Rene N5 substrates coated with single phase PtAl bond coat were grit blasted with 60 alumina grit at 80 psi (average roughness about 50 Ra) and heat treated at oxygen partial pressure 10x –6, -5, -4, and 1000 Mbar at 2050F for 2 to 4 hours. 7YSZ ceramic topcoat was applied by EBPVD process. The samples were tested in FCT1 hour cycle test at 2125F. The results are shown in Figure 2. Historical baseline for this type of sample is 230 cycles. It is clear that the partial pressure of oxygen has a significant effect, with the optimum being found at 10 x -4 Mbar (further work to determine this parameter window is in progress).

WITNESSED :

obvious internal oxidation. This difference is probably due to presence of fine grains of the second phase at the surface of the 2 phase PtAl coating. This provides extensive network of short paths for both oxygen diffusion inward (internal oxidation) and Al diffusion outward ("whiskers"). This examples proves again that the particular coating microstructure and chemical composition determine the conditions of the preoxidation treatment for the TBC life benefit.

Work to determine exact oxygen pressure "window" as well as optimum time and temperature is being preformed under GEAE IR&D program.

D. Description and operation:

<u>The present invention claims:</u>

(Pt,Ni Al)

Al from Vapor phase

1) Preoxidation heat treatment of PtAl single phase at low oxygen partial pressure range higher or equal to 10 x –5 mbar but lower the 1000 Mbar, with the optimal pressure being in 10X-4 mbar range; 1050°
2) The heat up rate is not slower then 45 min to the temperature, with the optimum being 11 –15 min; too slow for deterministic results
3) Texturing the surface before the heat treatment by blasting the surface with alumina grit of 1200 to 80 grit size;
4) Temperature of application of the ceramic 7YSZ top coat on the PtAl coat with grown oxide film is not lower then 900C , with the preferred temperature being 950 – 1000C 850-1050°C is the ideal range

<u>F. New Features</u>:

Gives conditions of low oxygen partial pressure preoxidation treatment for single phase PtAl bond coat

<u>G. Disadvantages:</u>

Requires heat treatment step and may require special vacuum furnace with gas flow control

<u>H. Alternatives.</u>

None.

WITNESSED >

Jeffrey A. Pfaendtner
Joseph D Rigney

Irene Spitsberg

References

1. N.E. Ulion, D.L.Ruckle, U.S, Patent 4,414,249, "Method for Producing Metallic Articles Having Durable Ceramic Thermal Barrier Coating"
2. N.E. Ulion, N.P. Anderson, U.S. Patent 5, 262,245, "Advanced Thermal Barrier Coated Superalloy Components".
3. T.E. Stragman, P.A. Solfest, U.S. Patent 4, 880,614, "Ceramic Thermal Barrier Coatings with Alumina Barrier Interlayer".
4. W. Lih, E. Chang, B.C. Wau and C.H. Chao, Oxidation of Metals, Vol. 36, Nos ¾, 1991, pp. 221-138, " Effect of preoxidation on the properties of ZrO2-8wt.% Y2O3/Ni- 22Cr – 10Al – 1Y Thermal Barrier Coatings
5. J. Jedlinski and G. Borchardt, Oxidation of Metals, Vol 36, 1991, pp.317-337, "On the oxidation mechanisms of Alumina formers"

WITNESSED:

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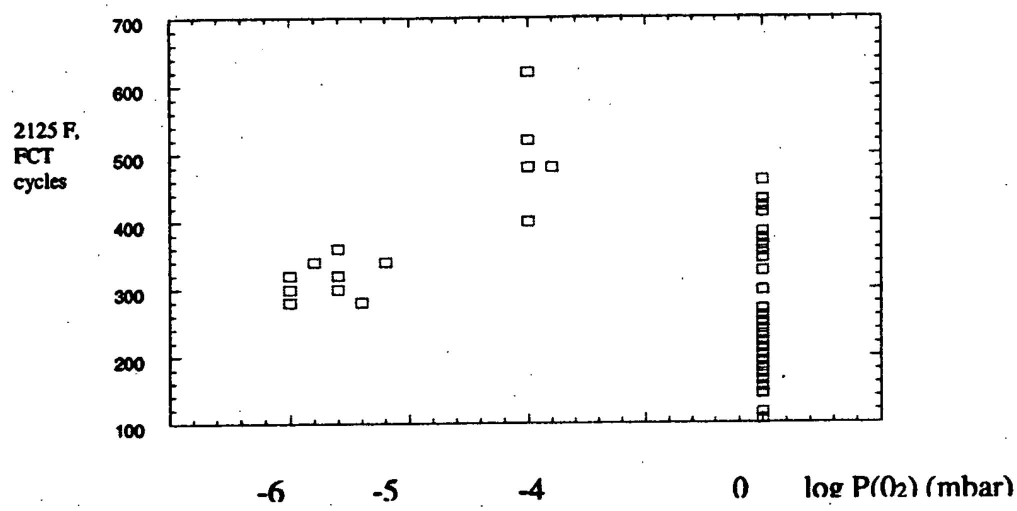
Joseph D Rigney

Irene Spitsberg

Figure 2. Effect of oxygen partial pressure in the preoxidation treatment on TBC performance.



Example 2 shows importance of the surface treatment before the preoxidation treatment.

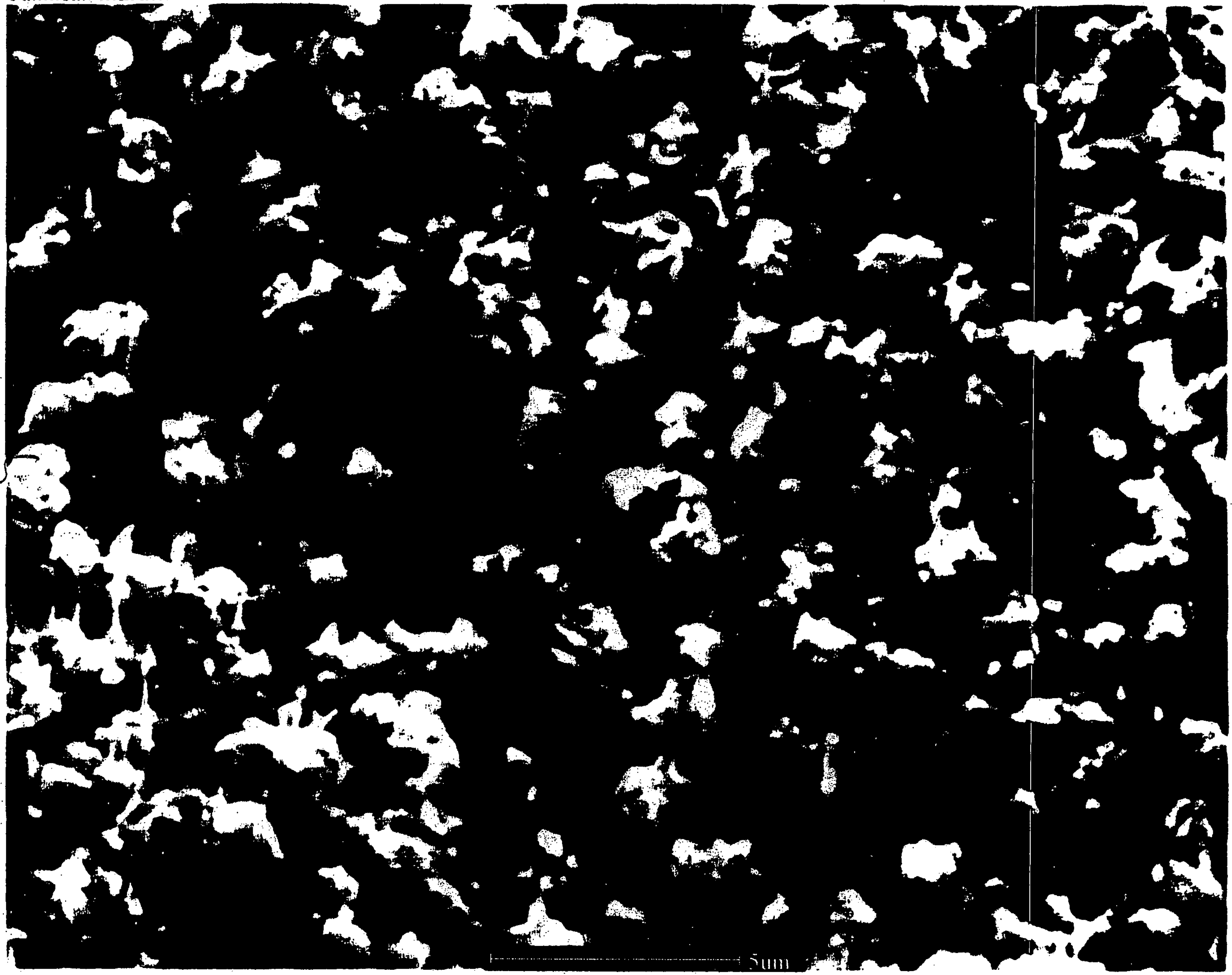
Rene N5 substrates coated with single phase PtAl bond coat were divided into 2 groups. Surface of one group was grit blasted with 60 alumina grit at 80 psi, whereas the other group was acid etched. "Cleanliness" of both procedures was assured by Auger surface analysis. Both groups of samples were preoxidized at 10 x –4 and –5 oxygen pressure at 2050F, coated with YSZ ceramic and tested as described in Example 1. The acid treated group did not show any advantage over the baseline, whereas the performance of the grit blasted group is demonstrated in Example 1.

Number of coatings with the oxide grown at different conditions was characterized using Scanning Electron Microscopy followed by depth profiling the oxides and measuring the oxide chemical composition by XPS technique. It was shown that oxidation at a high oxygen pressure results in not uniform oxide microstructure, with elements other then aluminum present in the oxide. When the preoxidation treatment done at low oxygen pressure, the grown oxide exhibits uniform compact "ridge" type microstructure characteristic of alpha alumina oxide (5), with no Ni or other but Al elements present in the oxide thickness. On the other hand, it is expected that going to even lower oxygen pressures will result into extensive internal oxidation and outward diffusion of Aluminum which would in turn result in poor adhesion of the oxide. Strong evidences of this were seen with preoxidation treatment of 2 phase PtAl coating at 10 x –5 oxygen pressure. Extensive internal oxidation with growth of oxide "whiskers pointing to the outward diffusion of Aluminum was observed as shown in Figure 3. As was mentioned above, the same heat treatment done on single phase PtAl resulted in very compact oxide with no

WITNESSED:

use PPO_2 with this phase – get whisker growing on islands

CamScan **MaXim**



Label:
SEI. WD=39.9 mm. EHT=20.0 kV. Image width=24.0 um. Spot size 5.00

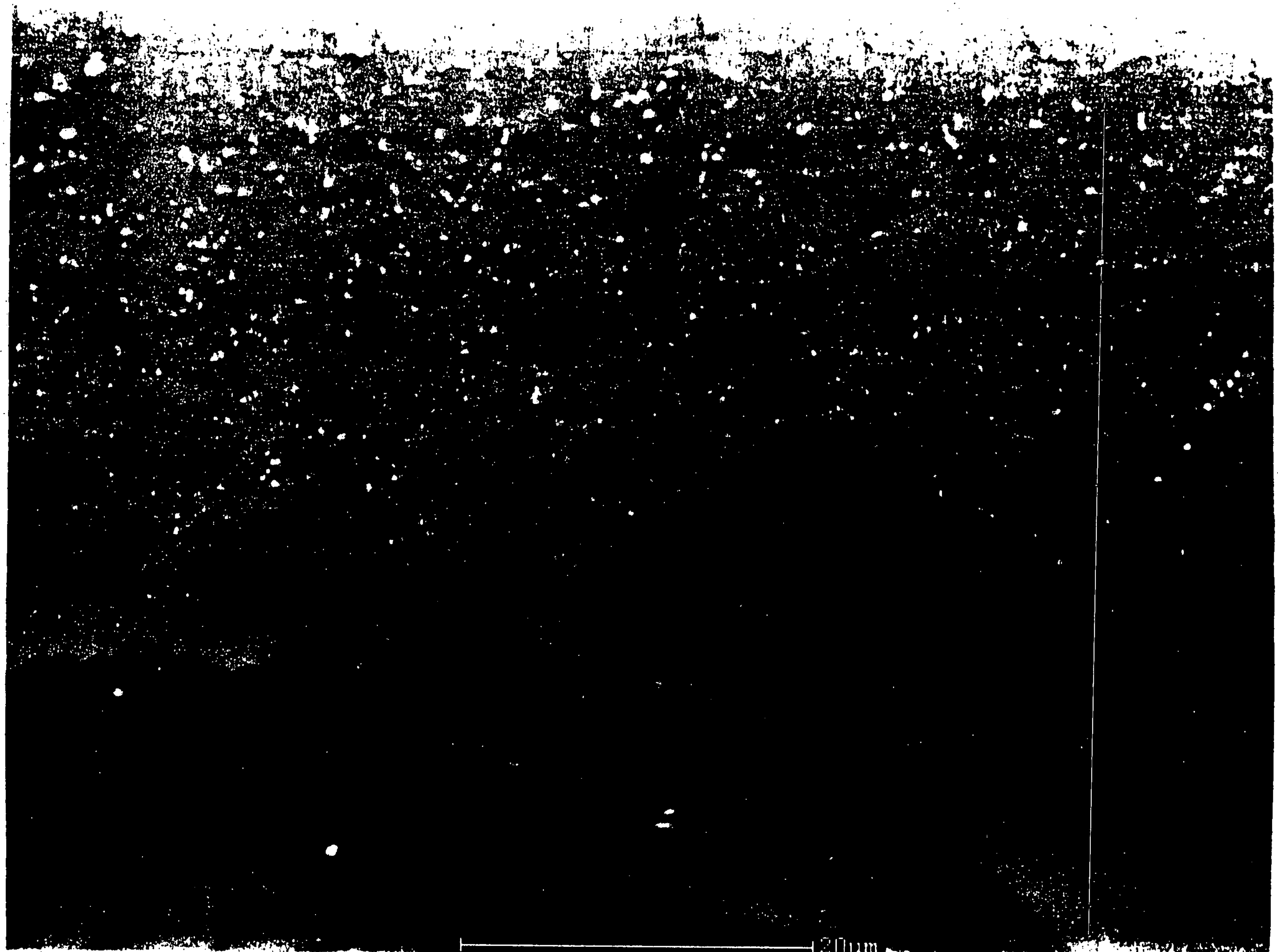
Figure 3, A. Oxide on the surface of PtAl 2 phase coating grown at 10^{-5} O_2 pressure.

WITNESSED:

[signatures]

Figure 3,8. Cross section view. Extensive internal oxidation.

CamScan MaXim



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BEI, WD=31.8 mm, EHT=20.0 kV, Image width=71.8 um, Spot size 3.00

WITNESSED:

Ultrasonic machining (USM) is a process in which a tool is given a high-frequency, low-amplitude oscillation, which, in turn, transmits a high velocity to fine abrasive particles that are present between the tool and the workpiece. Minute particles of the workpiece are chipped away on each stroke. Aluminum oxide, boron carbide, or silicone carbide grains are used in a water slurry (usually 50 percent by volume), which also carries away the debris. Grain size ranges from 200 to 1,000 (see Sec. 6 and Figs. 13.4.16 and 13.4.17).

The equipment consists of an electronic oscillator, a transducer (Fig. 13.4.21), a connecting cone or toolholder, and the tool. The oscillatory motion is obtained most conveniently by magnetostriction, at approximately 20,000 Hz and a stroke of 0.002 to 0.005 in (0.05 to 0.13 mm). The tool material is normally cold-rolled steel or stainless steel and is brazed, soldered, or fastened mechanically to the transducer through a

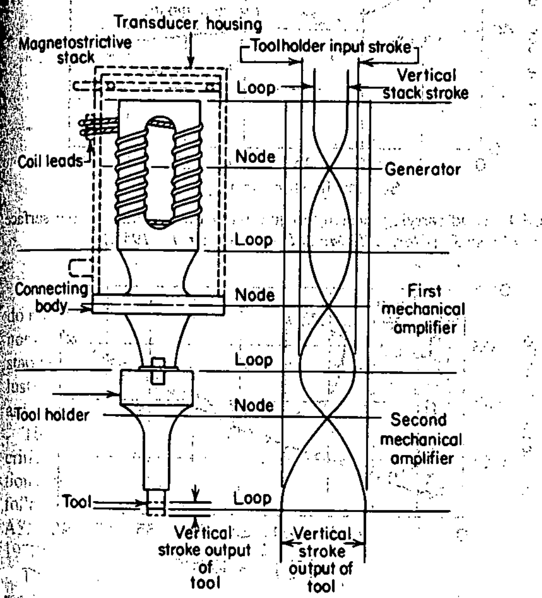


Fig. 13.4.21 Schematic diagram of a transducer used in the ultrasonic machining (USM) process.

toolholder. The tool is ordinarily 0.003 to 0.004 in (0.075 to 0.1 mm) smaller than the cavity it produces. Tolerances of 0.0005 in (0.013 mm) or better can be obtained with fine abrasives. For best results, roughing cuts should be followed with one or more finishing operations with finer grits. The ultrasonic machining process is used in drilling holes, engraving, cavity sinking, slicing, broaching, etc. It is best suited to materials which are hard and brittle, such as ceramics, carbides, borides, ferrites, glass, precious stones, and hardened steels.

In **abrasive-jet machining** (AJM), material is removed by fine abrasive particles (aluminum oxide or silicon carbide) carried in a high-velocity stream of air, nitrogen, or carbon dioxide. The gas pressure ranges up to 120 lb/in^2 (800 kPa), providing a nozzle velocity of up to 1,000 ft/s (300 m/s). Nozzles are made of tungsten carbide or sapphire. Typical applications are in drilling, sawing, slotting, and deburring of hard, brittle materials such as glass.

In **water jet machining** (WJM), water is ejected from a nozzle at pressures as high as 200,000 lb/in^2 (1,400 MPa) and acts as a saw. The process is suitable for cutting and deburring of a variety of materials such as polymers, paper, and brick in thicknesses ranging from 0.03 to 1 in (0.8 to 25 mm) or more. The cut can be started at any location, wetting is minimal, and no deformation of the rest of the piece takes place. Abrasives can be added to the water stream to increase material removal rate, and this is known as **abrasive water jet machining** (AWJM).

In **laser-beam machining** (LBM), material is removed by converting electric energy into a narrow beam of light and focusing it on the workpiece. The high energy density of the beam is capable of melting and vaporizing all materials, and consequently, there is a thin heat-affected zone. The most commonly used laser types are CO_2 (pulsed or continuous-wave) and Nd : YAG. Typical applications include cutting a variety of metallic and nonmetallic materials, drilling (as small as 0.0002 in or 0.005 mm in diameter), and marking. The efficiency of cutting increases with decreasing thermal conductivity and reflectivity of the material. Because of the inherent flexibility of the process, programmable and computer-controlled laser cutting is now becoming important, particularly in cutting profiles and multiple holes of various shapes and sizes on large sheets. Cutting speeds may range up to 25 ft/min (7.5 m/min).

The **electron-beam machining** (EBM) process removes material by focusing high-velocity electrons on the workpiece. Unlike lasers, this process is carried out in a vacuum chamber and is used for drilling small holes in all materials including ceramics, scribing, and cutting slots.

13.5 SURFACE TEXTURE DESIGNATION, PRODUCTION, AND CONTROL

by Thomas W. Wolff

REFERENCES: American National Standards Institute, "Surface Texture," ANSI/ASME B 46.1-1985, and "Surface Texture Symbols," ANSI Y 14.36-1978. Broadston, "Control of Surface Quality," Surface Checking Gage Co., Hollywood, CA. ASME, "Metals Engineering Design Handbook," McGraw-Hill. SME, "Tool and Manufacturing Engineers Handbook," McGraw-Hill.

Rapid changes in the complexity and precision requirements of mechanical products since 1945 have created a need for improved methods of determining, designating, producing, and controlling the surface texture of manufactured parts. Although standards are aimed at standardizing methods for measuring by using stylus probes and electronic transducers for surface quality control, other descriptive specifications are sometimes required, i.e., interferometric light bands, peak-to-valley by optical sectioning, light reflectance by commercial glossmeters, etc. Other parameters are used by highly industrialized foreign countries to solve their surface specification problems. These include the high-spot counter and bearing area meter of England (Talysurf); the total peak-to-valley, or R_1, of Germany (Perthen); and the R or average amplitude of surface deviations of France. In the United States, peak counting is used in the sheet-steel industry, instrumentation is available (Bendix); and a standard for specification, SAE J-911, exists.

Surface texture control should be considered for many reasons, among them being the following:

1. Advancements in the technology of metal-cutting tools and machinery have made the production of higher-quality surfaces possible.

2. Products are now being designed that depend upon proper quality control of critical surfaces for their successful operation as well as for long, troublefree performance in service.

3. Artisans who knew the function and finish requirements for all the parts they made have been replaced, in most cases, by machine operators who are not qualified to determine the proper texture requirements for critical surfaces. The latter must depend, instead, on drawing specifications.

4. Remote manufacture and the necessity for controlling costs have made it preferable that finish requirements for all the critical surfaces of a part be specified on the drawing.

5. The design engineer, who best understands the overall function of a part and all its surfaces, should be able to determine the requirement for surface texture control where applicable and to use a satisfactory standardized method for providing this information on the drawing for use by manufacturing departments.

6. Manufacturing personnel should know what processes are able to produce surfaces within specifications and should be able to verify that the production techniques in use are under control.

7. Quality control personnel should be able to check conformance to surface texture specifications if product quality is to be maintained and product performance and reputation ensured.

8. Too much control may be worse than too little; hence, overuse of available techniques may hinder rather than assist, there being no payoff in producing surfaces that are more expensive than required to ensure product performance to establish standards.

DESIGN CRITERIA

Surfaces produced by various processes exhibit distinct differences in texture. These differences make it possible for honed, lapped, polished, turned, milled, or ground surfaces to be easily identified. As a result of its unique character, the surface texture produced by any given process can be readily compared with other surfaces produced by the same process through the simple means of comparing the average size of its irregularities, using applicable standards and modern measurement methods. It is then possible to predict and control its performance with considerable certainty by limiting the range of the average size of its characteristic surface irregularities. Surface texture standards make this control possible.

Variations in the texture of a critical surface of a part influence its ability to resist wear and fatigue; to assist or destroy effective lubrication; to increase or decrease its friction and/or abrasive action on other parts; and to resist corrosion, as well as affect many other properties that may be critical under certain conditions.

Clay has shown that the load-carrying capacity of nitrided shafts of varying degrees of roughness, all running at 1,500 r/min in diamond-turned lead-bronze bushings finished to 20 μin (0.50 μm), varies as shown in Fig. 13.5.1. The effects of roughness values on the friction between a flat slider on a well-lubricated rotating disk are shown in Fig. 13.5.2.

Surface texture control should be a normal design consideration under the following conditions:

1. For those parts whose roughness must be held within closely controlled limits for optimum performance. In such cases, even the process may have to be specified. Automobile engine cylinder walls, which should be finished to about 13 μin (0.32 μm) and have a circumferential (ground) or an angular (honed) lay, are an example. If too rough, excessive wear occurs, if too smooth, piston rings will not seat properly, lubrication is poor, and surfaces will seize or gall.

2. Some parts, such as antifriction bearings, cannot be made too smooth for their function. In these cases, the designer must optimize the tradeoff between the added costs of production and various benefits derived from added performance, such as higher reliability and market value.

3. There are some parts where surfaces must be made as smooth as possible for optimum performance regardless of cost, such as gages, gage blocks, lenses, and carbon pressure seals.

4. In some cases, the nature of the most satisfactory finishing process may dictate the surface texture requirements to attain production efficiency, uniformity, and control even though the individual performance of the part itself may not be dependent on the quality of the controlled surface. Hardened steel bushings, e.g., which must be ground to close tolerance for press fit into housings, could have outside surfaces well beyond the roughness range specified and still perform their function satisfactorily.

5. For parts which the shop, with unjustified pride, has traditionally finished to greater perfection than is necessary, the use of proper surface texture designations will encourage rougher surfaces on exterior and other surfaces that do not need to be finely finished. Significant cost reductions will accrue thereby.

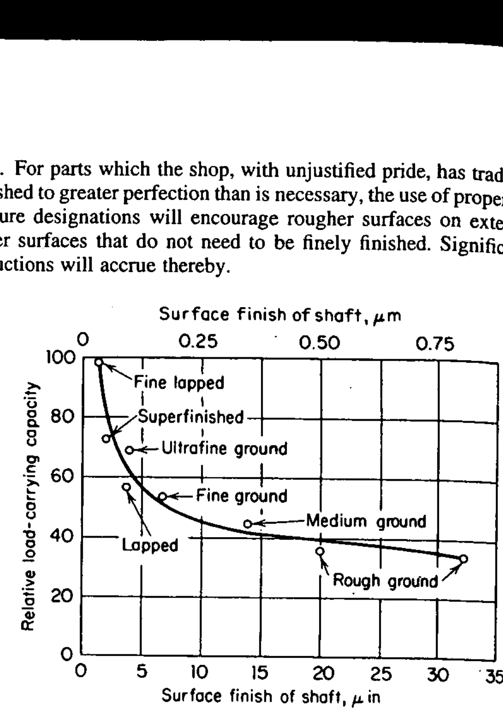


Fig. 13.5.1 Load-carrying capacity of journal bearings related to the surface roughness of a shaft. *(Clay, ASM Metal Progress, Aug. 15, 1955.)*

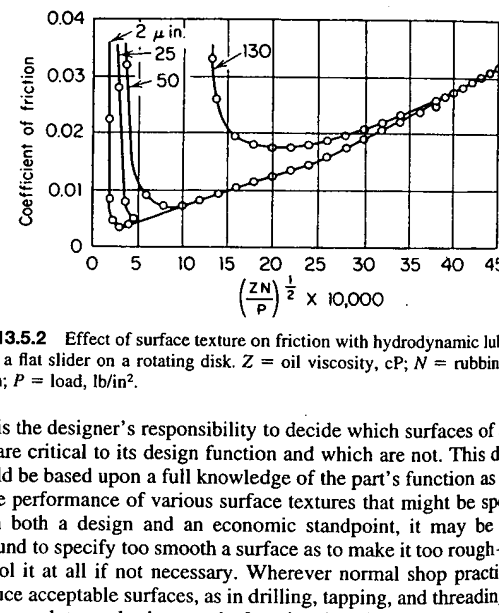


Fig. 13.5.2 Effect of surface texture on friction with hydrodynamic lubrication using a flat slider on a rotating disk. Z = oil viscosity, cP; N = rubbing speed, ft/min; P = load, lb/in^2.

It is the designer's responsibility to decide which surfaces of a given part are critical to its design function and which are not. This decision should be based upon a full knowledge of the part's function as well as of the performance of various surface textures that might be specified. From both a design and an economic standpoint, it may be just as unsound to specify too smooth a surface as to make it too rough—or to control it at all if not necessary. Wherever normal shop practice will produce acceptable surfaces, as in drilling, tapping, and threading, or in keyways, slots, and other purely functional surfaces, unnecessary surface texture control will add costs which should be avoided.

Whereas each specialized field of endeavor has its own traditional criteria for determining which surface finishes are optimum for adequate performance, Table 13.5.1 provides some common examples for design review, and Table 13.5.6 provides data on the surface texture ranges that can be obtained from normal production processes.

DESIGNATION STANDARDS, SYMBOLS, AND CONVENTIONS

The precise definition and measurement of surface texture irregularities of machined surfaces are almost impossible because the irregularities are very complex in shape and character and, being so small, do not lend themselves to direct measurement. Although both their shape and length may affect their properties, control of their average height and direction usually provides sufficient control of their performance. The standards

Table 13.5.1 Typical Surface Texture Design Requirements

Roughness	Typical applications
(250 μin) 6.3	Clearance surfaces; Rough machine parts
(125 μin) 3.2	Mating surfaces (static); Chased and cut threads; Clutch-disk faces; Surfaces for soft gaskets
(63 μin) 1.60	Piston-pin bores; Brake drums; Cylinder block, top; Gear locating faces; Gear shafts and bores; Ratchet and pawl teeth; Milled threads; Rolling surfaces; Gearbox faces; Piston crowns; Turbine-blade dovetails
(32 μin) 0.80	Broached holes; Bronze journal bearings; Gear teeth; Slideways and gibs; Press-fit parts; Piston-rod bushings; Antifriction bearing seats; Sealing surfaces for hydraulic tube fittings
(16 μin) 0.40	Motor shafts; Gear teeth (heavy loads); Spline shafts; O-ring grooves (static); Antifriction bearing bores and faces; Camshaft lobes; Compressor-blade airfoils; Journals for elastomer lip seals
(13 μin) 0.32	Engine cylinder bores; Piston outside diameters; Crankshaft bearings
(8 μin) 0.20	Jet-engine stator blades; Valve-tappet cam faces; Hydraulic-cylinder bores; Lapped antifriction bearings
(4 μin) 0.10	Ball-bearing races; Piston pins; Hydraulic piston rods; Carbon-seal mating surfaces
(2 μin) 0.050	Shop-gage faces; Comparator anvils
(1 μin) 0.025	Bearing balls; Gages and mirrors; Micrometer anvils

do not specify the surface texture suitable for any particular application, nor the means by which it may be produced or measured. Neither are the standards concerned with other surface qualities such as appearance, luster, color, hardness, microstructure, or corrosion and wear resistance, any of which may be a governing design consideration.

The standards provide definitions of the terms used in delineating critical surface-texture qualities and a series of symbols and conventions suitable for their designation and control. In the discussion which follows, the reference standards used are "Surface Texture" (ANSI/ASME B46.1-1985) and "Surface Texture Symbols" (ANSI Y14.36-1978).

The basic ANSI symbol for designating surface texture is the checkmark with horizontal extension shown in Fig. 13.5.3. The symbol with the triangle at the base indicates a requirement for a machining allowance, in preference to the old *f* symbol. Another, with the small circle in the base, prohibits machining; hence surfaces must be produced without the removal of material by processes such as cast, forged, hot- or cold-finished, die-cast, sintered- or injection-molded, to name a few. The surface-texture requirement may be shown at A; the machining allowance at B; the process may be indicated above the line at C; the roughness width cutoff (sampling length) at D, and the lay at E. The ANSI symbol provides places for the insertion of numbers to specify a wide variety of texture characteristics, as shown in Table 13.5.2.

Control of **roughness**, the finely spaced surface texture irregularities resulting from the manufacturing process or the cutting action of tools or abrasive grains, is the most important function accomplished through the use of these standards, because roughness, in general, has a greater effect on performance than any other surface quality. The roughness-height index value is a number which equals the arithmetic average deviation of the minute surface irregularities from a hypothetical perfect surface, expressed in either millionths of an inch (microinches, μin, 0.000001 in) or in micrometres, μm, if drawing dimensions are in metric, SI units. For control purposes, roughness-height values are taken from Table 13.5.3, with those in boldface type given preference.

The term *roughness cutoff*, a characteristic of tracer-point measuring instruments, is used to limit the length of trace within which the asperities of the surface must lie for consideration as roughness. Asperity spacings greater than roughness cutoff are then considered as waviness.

Waviness refers to the secondary irregularities upon which roughness is superimposed, which are of significantly longer wavelength and are usually caused by machine or work deflections, tool or workpiece vibration, heat treatment, or warping. Waviness can be measured by a dial indicator or a profile recording instrument from which roughness has been filtered out. It is rated as maximum peak-to-valley distance and is indicated by the preferred values of Table 13.5.4. For fine waviness control, techniques involving contact-area determination in percent (90, 75, 50 percent preferred) may be required. Waviness control by interferometric methods is also common, where notes, such as "Flat within XX helium light bands," may be used. Dimensions may be determined from the precision length table (see Sec. 1).

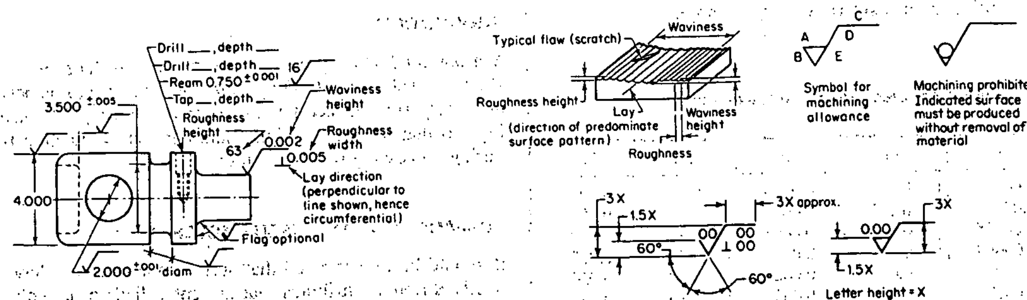


Fig. 13.5.3 Application and use of surface texture symbols.

Table 13.5.2 Application of Surface Texture Values to Surface Symbols

(63) 1.6√	Roughness average rating is placed at the left of the long leg. The specification of only one rating shall indicate the maximum value and any lesser value shall be acceptable. Specify in micrometres (microinches).	(63) 1.6 / 3.5 √	Machining is required to produce the surface. The basic amount of stock provided for machining is specified at the left of the short leg of the symbol. Specify in millimetres (inches).
(63) 1.6 (32) 0.8√	The specification of maximum value and minimum value roughness average ratings indicates permissible range of value rating. Specify in micrometres (microinches).	(63) 1.6√	Removal of material by machining is prohibited.
(32) 0.8√ 0.05	Maximum waviness height rating is placed above the horizontal extension. Any lesser rating shall be acceptable. Specify in millimetres (inches).	(32) 0.8√ ⊥	Lay designation is indicated by the lay symbol placed at the right of the long leg.
(32) 0.8√ 0.05 – 100	Maximum waviness spacing rating is placed above the horizontal extension and to the right of the waviness height rating. Any lesser rating shall be acceptable. Specify in millimetres (inches).	(32) 0.8√2.5 (0.100)	Roughness sampling length or cutoff rating is placed below the horizontal extension. When no value is shown, 0.80 mm is assumed. Specify in millimetres (inches).
		(32) 0.8√⊥0.5	Where required, maximum roughness spacing shall be placed at the right of the lay symbol. Any lesser rating shall be acceptable. Specify in millimetres (inches).

Table 13.5.3 Preferred Series Roughness Average Values R_a, μm and μin

μm	μin	μm	μin	μm	μin	μm	μin	μm	μin
0.012	0.5	0.125	5	0.50	20	2.00	80	8.0	320
0.025	1	0.15	6	0.63	25	2.50	100	10.0	400
0.050	**2**	**0.20**	**8**	**0.80**	**32**	**3.20**	**125**	**12.5**	**500**
0.075	3	0.25	10	1.00	40	4.0	160	15.0	600
0.10	**4**	0.32	13	1.25	50	5.0	200	20.0	800
		0.40	**16**	**1.60**	**63**	**6.3**	**250**	**25.0**	**1,000**

Lay refers to the direction of the predominant visible surface roughness pattern. It can be controlled by use of the approved symbols given in Table 13.5.5, which indicate desired lay direction with respect to the boundary line of the surface upon which the symbol is placed.

Flaws are imperfections in a surface that occur only at infrequent intervals. They are usually caused by nonuniformity of the material, or they result from damage to the surface subsequent to processing, such as scratches, dents, pits, and cracks. Flaws should not be considered in surface texture measurements, as the standards do not consider or classify them. Acceptance or rejection of parts having flaws is strictly a matter of judgment based upon whether the flaw will compromise the intended function of the part.

To call attention to the fact that surface texture values are specified on any given drawing, a note and typical symbol may be used as follows:

√ Surface texture per ANSI B46.1

Values for nondesignated surfaces can be limited by the note

XX√ All machined surfaces except as noted

Table 13.5.4 Preferred Series Maximum Waviness Height Values

mm	in	mm	in	mm	in
0.0005	0.00002	0.008	0.0003	0.12	0.005
0.0008	0.00003	0.012	0.0005	0.20	0.008
0.0012	0.00005	0.020	0.0008	0.25	0.010
0.0020	0.00008	0.025	0.001	0.38	0.015
0.0025	0.0001	0.05	0.002	0.50	0.020
0.005	0.0002	0.08	0.003	0.80	0.030

MEASUREMENT

Two general methods exist to measure surface texture: **profile methods** and **area methods**. Profile methods measure the contour of the surface in a plane usually perpendicular to the surface. Area methods measure an area of a surface and produce results that depend on area-averaged properties.

Another categorization is by **contact methods** and **noncontact methods**. Contact methods include stylus methods (tracer-point analysis) and capacitance methods. Noncontact methods include light section microscopy, optical reflection measurements, and interferometry.

Replicas of typical standard machined surfaces provide less accurate but often adequate reference and control of rougher surfaces with R_a over 16 μin.

The United States and 25 other countries have adopted the **roughness average R_a** as the standard measure of surface roughness. (See ANSI/ASME B46.1-1985.)

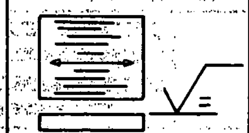
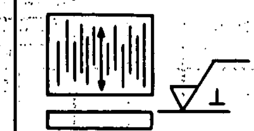
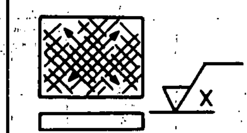
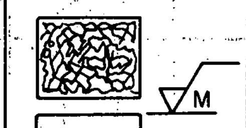
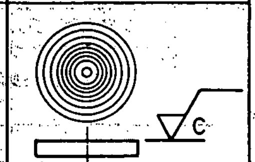
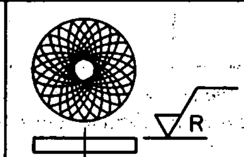
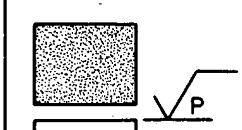
PRODUCTION

Various production processes can produce surfaces within the ranges shown in Table 13.5.6. For production efficiency, it is best that critical areas requiring surface texture control be clearly designated on drawings so that proper machining and adequate protection from damage during processing will be ensured.

SURFACE QUALITY VERSUS TOLERANCES

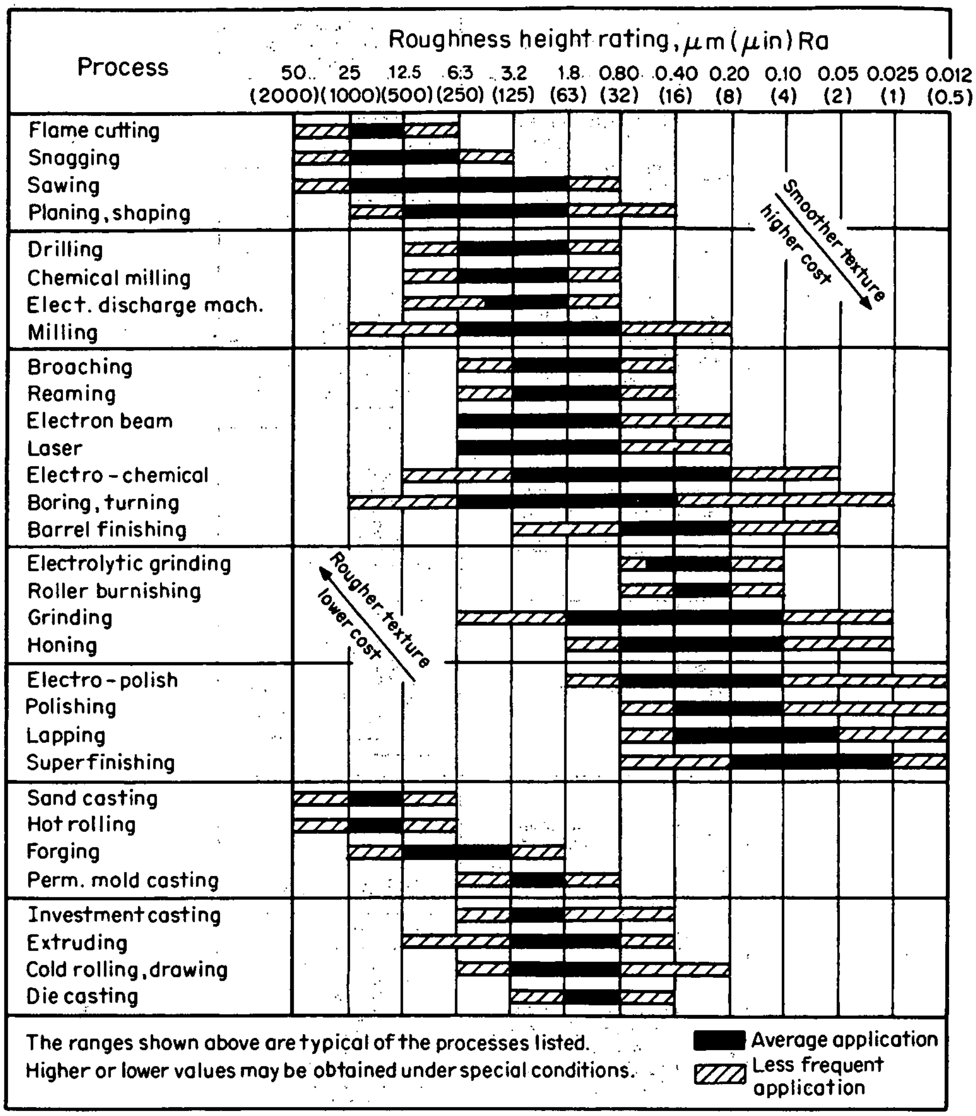
It should be remembered that surface quality and tolerances are distinctly different attributes that are controlled for completely separate purposes. **Tolerances** are established to limit the range of the size of a

Table 13.5.5 Lay Symbols

Lay symbol	Interpretation	Example showing direction of tool marks
=	Lay approximately parallel to the line representing the surface to which the symbol is applied	
⊥	Lay approximately perpendicular to the line representing the surface to which the symbol is applied	
X	Lay angular in both directions to line representing the surface to which symbol is applied	
M	Lay multidirectional	
C	Lay approximately circular relative to the center of the surface to which the symbol is applied	
R	Lay approximately radial relative to the center of the surface to which the symbol is applied	
P	Lay particulate, nondirectional, or protuberant	

ıe time of manufacture, as measured with gages, micrometres, traditional measuring devices having anvils that make contact part. Surface quality controls, on the other hand, serve to limit the minute surface irregularities or asperities that are formed by the manufacturing process. These lie under the gage anvils during measurement and do not use up tolerances.

Table 13.5.6 Surface-Roughness Ranges of Production Processes



13.6 WOODCUTTING TOOLS AND MACHINES

by Richard W. Perkins

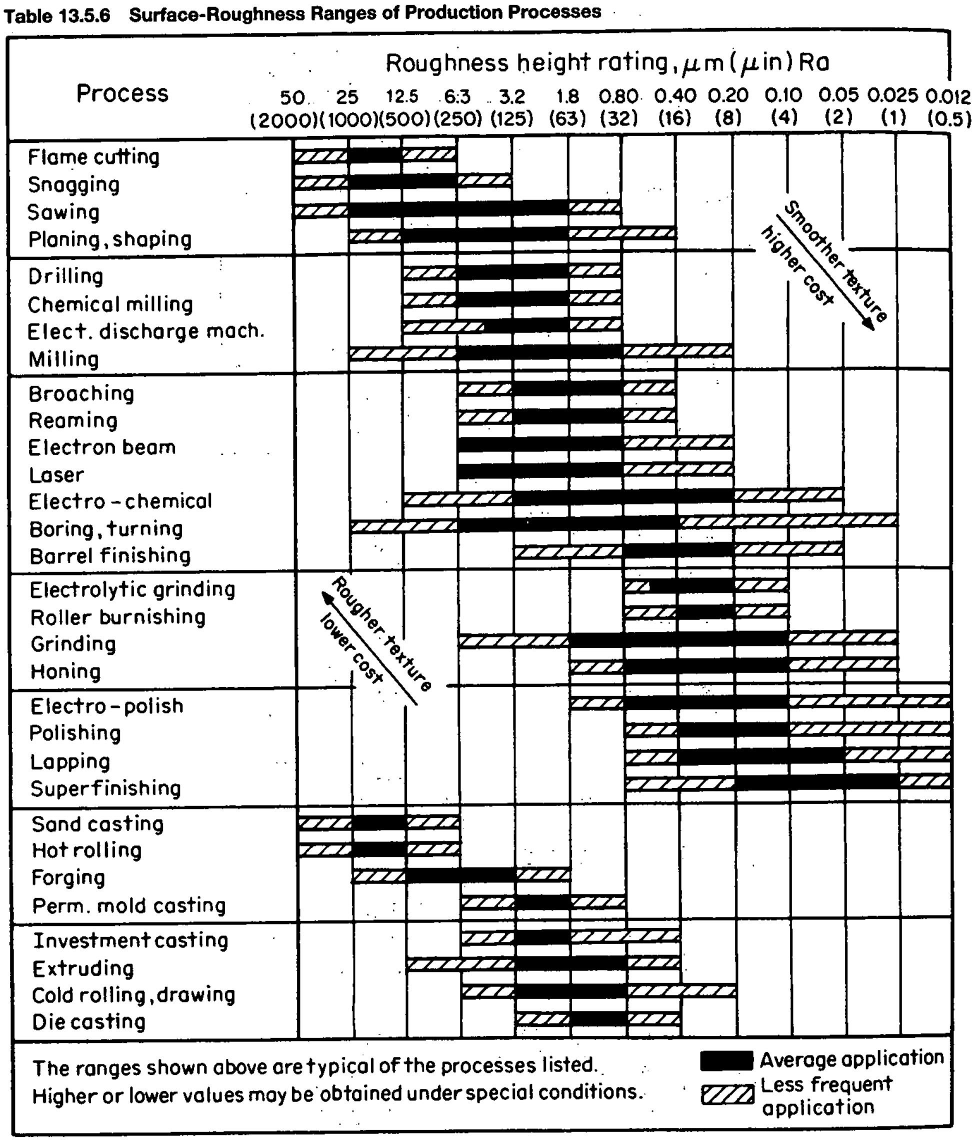
REFERENCES: Davis, Machining and Related Characteristics of United States Hardwoods, *USDA Tech. Bull.* 1267. Harris, "A Handbook of Woodcutting," Her Majesty's Stationery Office, London. Koch, "Wood Machining Processes," Ronald Press. Kollmann, Wood Machining, in Kollmann and Côté, "Principles of Wood Science and Technology," chap. 9, Springer-Verlag.

SAWING

Sawing machines are classified according to basic machine design, i.e., band saw, gang saw, chain saw, circular saw. Saws are designated as **ripsaws** if they are designed to cut along the grain or **crosscut** saws if they are designed to cut across the grain. A **combination** saw is designed to cut reasonably well along the grain, across the grain, or along a direction at an angle to the grain (**miter**). Sawing machines are often further classified according to the specific operation for which they are used, e.g., **headsaw** (the primary log-breakdown saw in a sawmill), **resaw** (saw for ripping cants into boards), **edger** (saw for edging boards in a sawmill), **variety saw** (general-purpose saw for use in furniture plants), **scroll saw** (general-purpose narrow-band saw for use in furniture plants).

The thickness of the saw blade is designated in terms of the Birming-

Table 13.5.6 Surface-Roughness Ranges of Production Processes



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The thickness of the saw blade is designated in terms ...